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PLATE 13.

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THE USE OF TWO SCINTILLATION COUNTERS IN BETA RAY SPECTROSCOPY

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(*Plate* 13)

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In nuclear physics one is often interested, not only in counting the number of particles coming from, say, a radioactive source, but also in determining their energy distribution. What may be termed direct and indirect means are available for doing this. The former is exemplified by the determination of beta particle energies by observing the radius of curvature of the circles into which they are bent by a known magnetic field. All indirect methods (of which this paper describes one) first convert the energy of the particles into electrical voltage pulses, and then examine the distribution of these pulses with some form of pulse sorter. This conversion to electrical energy is usually done by either proportional or scintillation counter. The experiments described here were actually carried out with a scintillation counter, using anthracene and sodium iodide crystals for the detection of beta and gamma radiation. Essential details of the set-up will be given later at appropriate points, as this paper is intended to deal chiefly with the subsequent problem of pulse sorting.

The commonest forme of pulse sorting is by electronic means. Valve discriminator circuits are well known which give out a standard pulse when a pulse greater than a certain value E is fed in. By varying the value of E, an integral pulse spectrum may be obtained, and hence, by calculation, a differential spectrum. To obtain directly the differential spectrum two discriminator circuits set at E and E+dE, respectively, may be placed in anticoincidence. Again, by varying E, the whole spectrum may be covered. dE is typically 1 or 2 volts with E varying from 0 to 100 volts, so quite considerable amplification of the incoming pulses is usually required. Furthermore, the circuits involved are relatively complicated, and not entirely reliable (1).

An alternative arrangement (2) is to present the pulses on the screen of a triggered oscilloscope as shown in Fig. 1. Here the pulses rise very rapidly, and decay with a time constant depending on the circuit parameters. The pattern thus produced on the screen is photographed with an exposure time sufficiently long for a large number of pulses to arrive. After the film has been processed, a microphotometer traversing across the film, as shown by the dotted line, gives immediately the differential spectrum. This method, however, suffers from two disadvantages.

FIG. 1.

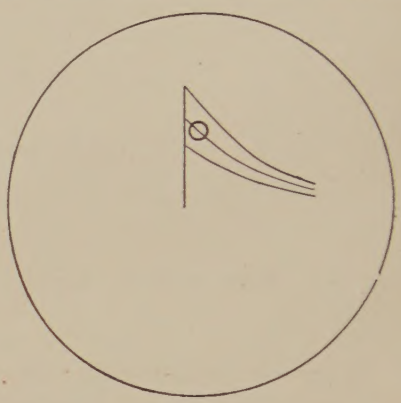

FIG. 2.

Firstly, the film processing takes a relatively long time, and, secondly, the film blackening is not necessarily directly proportional to the number of pulses arriving. The method to be described below, which consists essentially of a telescoping of the pulse presentation on the screen and the later scanning, does not suffer from either of the above mentioned disadvantages.

Pulses from a scintillation counter are again displayed on the screen of an oscilloscope (actually a Cossor model 1035), the 50 microsecond sweep being triggered internally by the pulses, and the trace brightened by an external circuit. The oscilloscope amplifier provided all the gain necessary. The screen was entirely masked with black perspex, except for a small hole (diameter 0.3 mm. approximately), at a distance of 2 cm. vertically above the centre. This hole is viewed by an R.C.A. photomultiplier, type 5819, operating at 1070 volts, and feeding directly to a scale of 64 recorder. Fig. 2 shows how the differential action is obtained. Of the three pulse traces displayed on the screen, only the one crossing the hole will be counted by the photomultiplier. For a sufficiently small hole (such as the one used), the resolution obtainable is limited by the width of the oscilloscope trace. To scan the whole energy spectrum of the pulses, the hole may be moved vertically or, more practically, the complete pattern on the screen may be moved by means of the oscilloscope Y shift. A manual slow motion drive was fitted specially for this purpose. Plate 13 shows a photograph of the apparatus. On the extreme left is a precision potentiometer for monitoring the high voltage supplies for the photomultipliers.

Beside it is the steel tube containing the scintillation counter and source. The rack contains the two high voltage supplies, and the trace brightener (at bottom). To the right of this is the oscilloscope with the R.C.A. photomultiplier in its light shield projecting out from the front, and at the extreme right comes the scale of 64. The oscilloscope sitting on the scaler is used for inspection of the pulses entering the latter, but the apparatus to the right of the oscilloscope was not used in this series of experiments.

Fig. 3 shows a run on the Cs^{137} spectrum, with its 0.63 Mev internal conversion line, the data being obtained in about three-quarters of an hour. The scintillation counter itself consisted of an anthracene crystal (size 1.5 cm. × 1.5 cm. × 1.5 cm.) and an E.M.I. photomultiplier, type 6446, operated at 1340 volts. The source was made by placing a drop of caesium solution directly on the thin aluminium reflector surrounding the crystal, and allowing it to evaporate. The energy resolution obtained

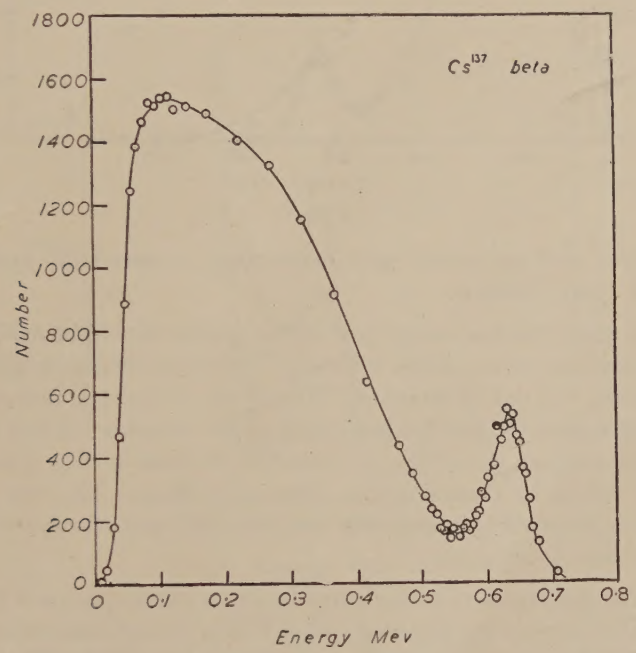

FIG. 3.

(*i.e.* the value of dE/E where dE is the width of the line at half maximum and E is its energy) is approximately 11%. Since a resolution of about 10% at 0.7 Mev is a usual figure for scintillation counters (3), it is clear that in this case it is statistical processes in the multiplier and crystal which are limiting the resolution, and not the pulse sorter. In fact runs on caesium by the author with an electronic pulse sorter under roughly the same conditions gave resolutions considerably worse than that above.

The energy scale in Fig. 3 is obtained from the position of the Cs^{137} internal conversion line itself and its known energy (0·63 Mev) since, experimentally, only arbitary numbers on the slow motion drive giving the Y shift position were obtained.

Fig. 4 shows a spectrum of RaE with the caesium line again superimposed to give energy calibration. The arrow shows the predicted end point of the RaE spect-

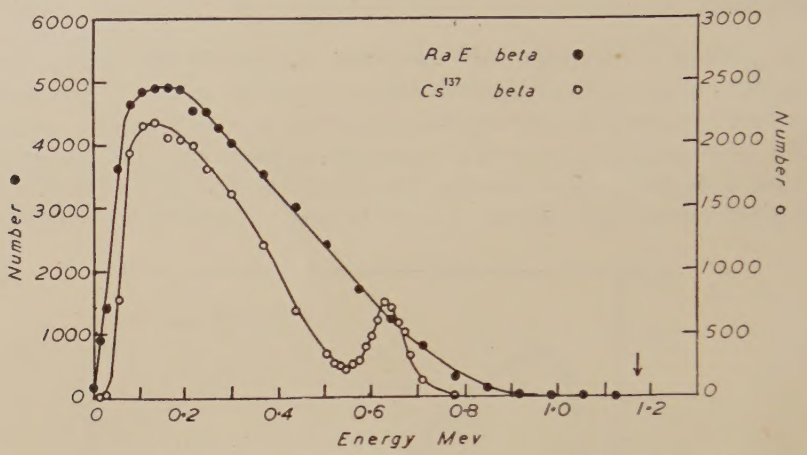

FIG. 4.

rum (1·17 Mev), and agreement with experiment is reasonably good, considering the long RaE ' tail ' present.

A remark about the low energy part of the spectra should be made at this stage. Since the oscilloscope sweep needs a pulse of a certain definite height to trigger it, very small pulses will not be recorded. Therefore, all spectra, independent of their real shape, will appear to have too few pulses at low energies—in fact all the spectral curves will pass through the origin. The curves obtained in Figs. 3 and 4, therefore, are probably not to be trusted below about 0·15 Mev. The true spectra would almost certainly show a large number of very low electrons, on account of the various scattering processes occurring.

Gamma ray spectroscopy is illustrated in Fig. 5 where spectra of Cs^{137} and Au^{198} are shown. The curves were obtained with a NaI crystal of dimensions 1 cm. × 1 cm. × 1 cm., and small liquid sources enclosed in glass ampoules of sufficient thickness to screen out the beta particles. In the caesium spectrum one sees the photoelectric peak at 0·66 Mev, and the Compton peak at approximately 0·43 Mev. Once again, the energy scale has been calibrated by the caesium photoline. On this scale the gold photoline appears at 0·425 Mev, which agrees well with the accepted value of 0·41 Mev. The peak on the gold spectrum at about 0·2 Mev is roughly at the position where the Compton peak should be, but, as on other occasions a ' ghost ' peak due to scattering (2) appeared around here, the significance of the peak on the graph is not altogether certain.

Directions in which it would seem possible to improve the analyser resolution would be, firstly, by using an oscilloscope with a better screen diameter to spot size ratio, and, secondly, by better stabilisation of the oscilloscope. The Cossor model 1035, although an admirable instrument in many respects, suffers from the defect that the positive high tension supply for the amplifiers is not electronically stabilised. This probably accounts for the slight up-and-down wobble of the spot when fluctuations in A.C. input occur. This wobble could conceivably flatten the top

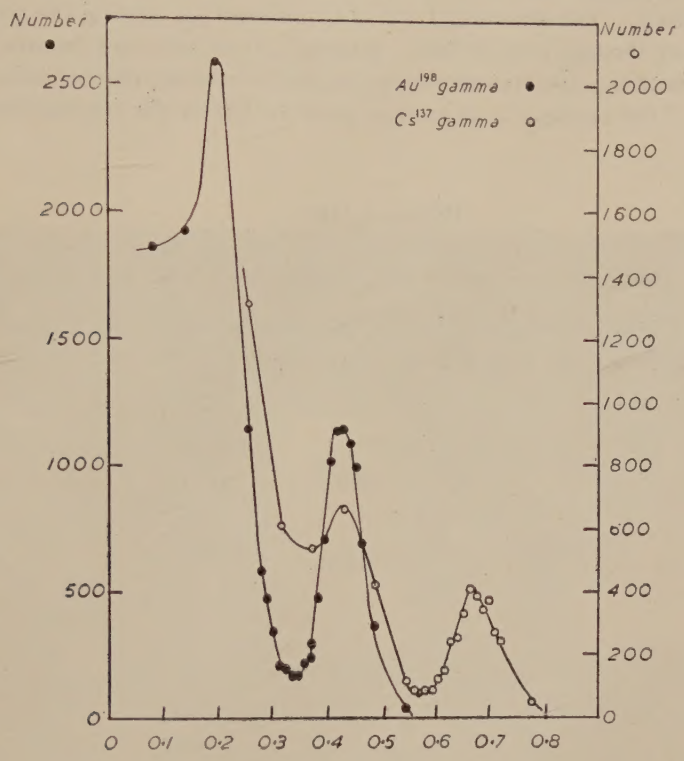

FIG. 5.

of a sharp spectral peak, and thus reduce the resolution. A very high degree of stability is, of course, also required for the H.V. supply for the photomultipliers, as their gain varies as the seventh power of the applied voltage.

Improvements in stabilisation as indicated above were effected by running the oscilloscope from an 'Advance' constant voltage transformer, and by replacing the VR150 tubes in the H.V. power packs by the better 85A2 type. No significant improvement in resolution was, however, observed; but this, as pointed out previously, is almost certainly due to the fact that the limit of resolution of the scintillation counter itself had already been reached.

In conclusion, the author wishes to acknowledge his indebtedness to Prof. J. H. J. Poole for much helpful advice, and to Dr. Riordan of the Royal City of Dublin Hospital for specimens of Au^{198}.

Summary.

A simple pulse height analyser, which is based on oscilloscopic presentation of the pulses, is described. The differential action is obtained by viewing the screen with a photomultiplier through a small hole. Examples from beta and gamma spectroscopy with a scintillation spectrometer are given, and it is shown that for such methods the resolution of the analyser is at least as good as that of the scintillation counter itself.

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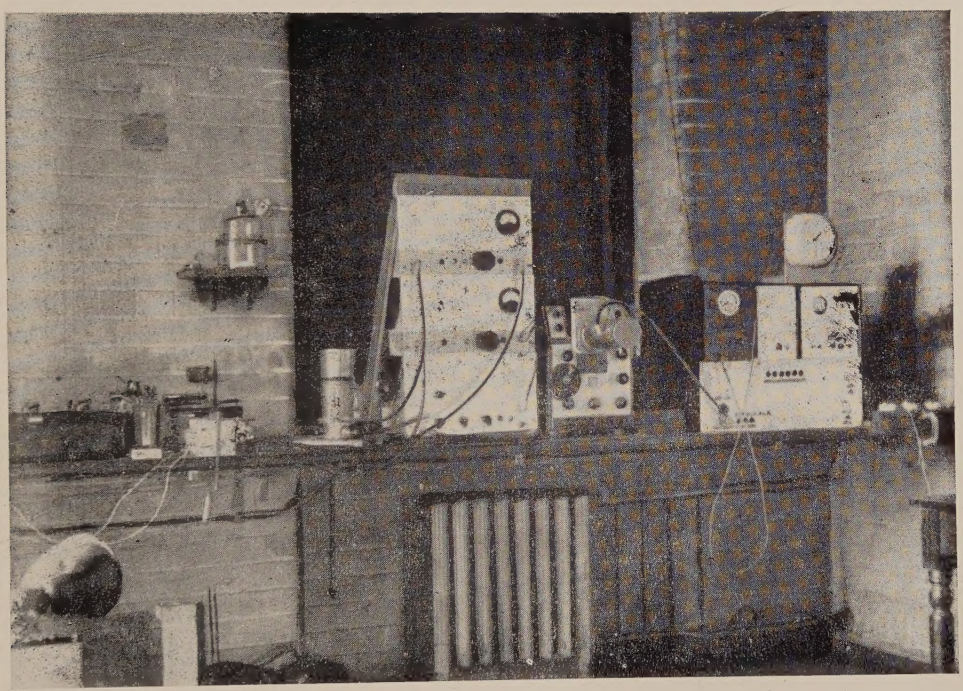

The Apparatus. [*See pages* 174 *and* 175.